U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: PROCEDURES FOR CONDUCTING FUEL SYSTEM HOT WEATHER OPERATION TESTS

Date: 1/14/87 **Initiated by:** ACE-100 **AC No:** 23.961-1 **Change:**

1. PURPOSE. This advisory circular (AC) provides information and guidance concerning an acceptable means, but not the only means, of showing compliance with Part 3 of the Civil Air Regulations (CAR) and Part 23 of the Federal Aviation Regulations (FAR) applicable to procedures for conducting fuel system hot weather operation tests in small airplanes. Accordingly, this material is neither mandatory nor regulatory in nature and does not constitute a regulation.

2. RELATED FAR SECTION. Listed below are the applicable FAR sections and the related CAR sections of Part 3 shown in parenthesis:

a. § 23.961 (3.438).

b. § 23.951 (3.429).

3. BACKGROUND. Section 23.961 (3.438) requires each fuel system that may form vapor to be free of vapor lock when using fuel at a temperature of 110°F under critical operating conditions. Several factors are involved in the evaluation of an airplane fuel system for hot weather which should consider at least the following:

a. Airplanes parked in direct sunlight may experience significant elevated fuel temperature, to 110°F or higher, even when the air temperature is less. The likelihood of vapor formation and subsequent interruption of engine power increases with elevated fuel temperature up to 110°F.

b. The tendency of various fuels to form vapor is different. Fuels such as automobile gasoline (autogas) have an initial boiling point of approximately 85°F whereas some turbine fuels have an initial boiling point of approximately 120°F. Since the initial boiling point is a vapor temperature, the actual fuel temperature for the initial boiling point is greater than the vapor temperature. The tendency to form vapor may be related to Reid vapor pressure (RVP) with the higher values being more conducive to vapor formation. Tests conducted by the FAA Technical Center, Atlantic City, New Jersey, with winter-grade autogas, indicate that autogas should be heated above 100°F, not to exceed 110°F, in order to produce the maximum vapor formation. Heating autogas with an RVP greater than 12.5 pounds per square inch (PSI) above 110°F will result in a spontaneous and immediate weathering effect on the fuel.

c. The regulation requires that the critical operating conditions need to be considered during evaluation of hot weather tests which would include at least the maximum fuel flow, high angle of attack, maximum fuel temperature, etc.

d. A flight test is normally necessary to complete the hot weather operation tests. If a ground test is performed, it should closely simulate flight condition.

e. Any fuel system that uses aviation or automotive fuels is considered conducive to vapor formation including a gravity feed system. However, a fuel system having a fuel pump with suction lift is more critical with respect to vapor formation.

f. Tests conducted by the FAA Technical Center indicate that fuel should not be allowed to weather for any significant period. Any weathering, including exposure to the atmosphere overnight, may have a significant effect on the RVP. Also, the heating of fuel should be completed in the shortest time period possible, such as less than 90 minutes but not to exceed 180 minutes.

g. Fuel system designs should be evaluated for compliance with the FAR and to verify that fuel lines are not routed close to hot exhaust systems that may cause an increase of fuel temperature in the fuel lines.

h. Tests conducted by the FAA Technical Center indicate that for small airplanes with shallow depth fuel tanks that the fuel level in the tanks has very little effect on hot weather test results.

i. Tests conducted by the FAA Technical Center indicate that outside air temperature below 85°F may have a significant effect on the hot weather test results.

4. DEFINITIONS.

a. Initial boiling point - The vapor temperature at which the first drop of liquid fuel is observed after passing vapor through a distillation test apparatus.

b. Fuel volatility - The tendency to change a fluid from liquid to vapor.

c. Vapor lock - The tendency of a liquid to form vapor in fuel lines, pumps, etc., that would restrict liquid fuel flow to the engine and interrupt combustion.

d. True vapor pressure - The pressure exerted by its vapor in equilibrium with the liquid at a specific temperature with the absence of air over the fuel. For gasoline, the vapor pressure is determined by the Reid method.

e. Weathering - The reduction of fuel volatility when given sufficient time, agitation, temperature cycles, and/or pressure changes.

5. ACCEPTABLE MEANS OF COMPLIANCE.

a. Fuel that is unweathered or has not been exposed to long storage periods should be used during the tests. This ensures that the fuel has the maximum RVP for which approval is requested. As an example, if autogas is being tested, maintain a high volatile autogas or winter-grade fuel having an RVP of 12.5

psi or higher in a sealed container at a cool temperature (below 60°F) until ready for hot weather operation tests. Fuel samples for autogas only should be taken and analyzed just prior to the flight test to verify that the maximum vapor pressure desired is being evaluated.

b. The weight of the airplane should be the weight with critical fuel level, minimum crew necessary for safe operation, and the ballast necessary to maintain the center of gravity within allowable limits. The critical fuel level in most cases would be low fuel; however, in some cases, full fuel may be critical.

c. Raise the temperature of the fuel to the critical value as follows:

(1) For aviation gasoline, 110°F - 0 to +5°F.

(2) For automobile gasoline, 110°F - 5 to +0°F.

(3) For turbine fuel, 110°F - 0 to +5°F or up to the maximum outside air temperature for which approval is requested.

Testing of avgas is critical with respect to vapor formation when the fuel is heated to 110°F. Testing of autogas at the extreme RVP values would be critical when the fuel is heated to a temperature not to exceed 110°F. Heating autogas above 110°F may result in less conservative test results. Testing should commence immediately after the fuel temperature reaches its required value.

d. Several methods of heating the fuel are available, such as circulating hot water or steam through a heat exchanger placed in the fuel tank to increase the fuel temperature, placing black plastic or other material on the fuel tanks in bright sunlight, or blowing hot air over the fuel tank. The fuel should not be agitated or handled excessively during the heating process. The heating process should be completed in the shortest time period possible without causing excessive local temperature conditions at the heat exchanger.

CAUTION: Heating and handling fuel at elevated temperatures may be hazardous to ground and flight personnel; therefore, every safety precaution should be taken.

e. The desirable outside air temperature measured at 4' to 6' above the runway surface should be at least 85°F. If tests are performed in weather cold enough to interfere with test results, steps should be taken to minimize the effects of cold temperature. This may be accomplished by insulating fuel tank surfaces, as appropriate; fuel lines; and other fuel system components from the cold air to simulate hot-day conditions.

f. The takeoff and climb should be made as soon as possible after the fuel in the tank reaches the required test temperature in accordance with paragraph 5c, and the engine oil temperature should be at least the minimum recommended for takeoff. The critical operating conditions should be tested with at least consideration of the following:

(1) The airspeed in the climb should be the same as that used in demonstrating the requirements specified in § 23.65, except the airplane should be at minimum weight with a critical quantity of fuel in the tanks as discussed in paragraph 5b.

(2) Power settings should be maintained at the maximum approved levels for takeoff and climb to provide for the maximum fuel flow.

g. The climb should be continued to the maximum operating altitude approved for the airplane. If a lower altitude is substantiated, appropriate limitations should be noted in the Airplane Flight Manual (AFM).

h. Tests should be conducted with the fuel system operating normally in accordance with the normal procedures outlined in the AFM.

i. The following data should be recorded:

(1) Fuel temperature in the tank.

(2) Fuel pressure at the start of the test and continuously during climb noting any pressure failure, fluctuation, or variations.

(3) Main and emergency fuel pump operation, as applicable.

(4) Pressure altitude.

(5) Ambient air temperature, total or static as applicable.

(6) Airspeed.

(7) Engine power, i.e., engine pressure ratio, gas generator speed, torque, r.p.m., turbine inlet temperature, exhaust gas temperature, manifold pressure, and fuel flow, as appropriate.

(8) Comments on engine operation.

(9) Fuel quantities in the fuel tank(s) during takeoff.

(10) Fuel vapor pressure for autogas only, determined prior to test.

(11) Fuel grade or designation, determined prior to test.

j. A fuel pressure failure is considered to occur when the fuel pressure decreases below the minimum prescribed by the engine manufacturer or the engine does not operate satisfactorily.

k. The emergency fuel pumps should be inoperative if they are being considered for use as backup pumps. This test may be used to establish the maximum pressure altitude for operation with the pumps off.

l. It should not be necessary to provide additional heat for the fuel system after the original fuel sample is heated to temperature during the hot weather tests.

m. If significant fuel pressure fluctuations occur during testing of the critical flight condition but pressure failure does not occur, additional testing should be considered to determine that pressure failure may not occur during any expected operating mode. Also, the fuel system should be evaluated for vapor formation during cruise flight at maximum approved altitude in smooth air at low to moderate power setting and low fuel flow and idling approach to landing.

n. Appropriate Airplane Flight Manual (AFM) instructions may be necessary concerning proper use of fuel pumps during hot weather operations. Also, any limitation on the outside air temperature as a result of hot weather tests should be included in the AFM.

o. The hot weather tests may have to be repeated if the critical tank cannot be positively identified.

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